Testimony of

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Summary

Climate change poses health risks for U.S. populations, both direct impacts on health as well as through altering the systems on which human health and well-being depend. Although data in the U.S. are limited, health impacts due to climate change may already by occurring, with the magnitude and extent of impacts expected to increase with increasing climate change. The health risks of current and future climate change in the U.S. include greater numbers of illnesses and deaths due to (Ebi et al. 2008):

- Increases in the frequency, intensity, and length of heatwaves, with the highest risks among older adults, those with chronic medical conditions, infants and children, pregnant women, urban and rural poor, and outdoor workers. With limited mitigation or adaptation, heat-related mortality is projected to increase several-fold.
- Increases in the frequency and intensity of other extreme weather events, including floods, droughts, wildfires, and windstorms, with the risks highest among the poor, pregnant women, those with chronic medical conditions, and those with mobility and cognitive constraints. Projecting additional health burdens is difficult because these events are, by definition, rare. However, the impacts can be large for single events.
- Higher concentrations of ground-level ozone, with the highest risks among asthmatics and those with chronic heart or lung diseases, diabetics, athletes, and outdoor workers. Without taking into account possible changes in the precursors that are required for ozone formation, ozone-related mortality is projected to increase 4% by 2050 in the New York area. Ozone-related morbidity also would be expected to increase, including more asthma attacks in susceptible individuals.
- Certain diarrheal diseases, with the highest risks among older adults, infants, and those who are immunocompromised. Several studies have found that the number of reports of cases of salmonella, which has caused several recent foodborne outbreaks in the U.S., increases with increasing temperature.
- Possible changes in the geographic range and incidence of vectorborne and zoonotic diseases. There are several reports of infectious diseases appearing in areas that had previously been considered too cold for their transmission.
- Other health impacts also may increase. For example, there are anecdotal reports of increases in suicide rates among Native Alaskans associated with the loss of lands and livelihoods because of melting permafrost, loss of sea ice, and other changes due to climate change.

Demographic trends, such as a larger and older U.S. population, will increase overall vulnerability to these health risks. In addition, the U.S. population may be at risk from climate-related diseases and disasters that occur outside U.S. borders, with travelers and refugees importing diseases not currently present. The unprecedented nature of climate change also may bring unanticipated consequences for public health.

The magnitude and extent of these impacts will vary significantly across regions, requiring understanding of the local factors that interact with climate change to increase

the health risks. Adaptation and mitigation are equally important for addressing these risks. Neither is sufficient in itself; focusing only on mitigation would leave communities inadequately prepared for changes expected in the short term, and focusing only on adaptation would increase the amount of future climate change to which communities would need to adapt. There will be limits to the degree to which adaptation can reduce health burdens due to climate change.

In addition to increasing the public health capacity to prepare for and effectively respond to climate change, there is an urgent need to evaluate the possible health consequences of policies and technologies being developed to reduce emissions of greenhouse gases, from energy efficiency policies to carbon capture and storage. Responses to climate change may alter energy, transportation, and other systems required for our societies to function; health risks may arise from changes in any of these systems. Better understanding is needed of how these systems interact with health, including risks and opportunities for interventions to improve population health.

1.0 The Potential Health Impacts of Climate Change

The observation that major causes of ill health exhibit distinct seasonal patterns suggests *a priori* that weather and/or climate influence their distribution and incidence. Weather, climate variability, and climate change affect a wide range of health outcomes directly and indirectly. Directly, heatwaves, floods, droughts, windstorms, and fires annually affect millions of people and cause billions of dollars of damage. In 2003 in Europe, Canada, and the United States, floods and storms resulted in 101 people dead or missing and caused $9.73 billion in insured damages (Swiss Re 2004). More than 35,000 excess deaths were attributed to the extended heatwave in Europe the same year (Kostasky 2005). The frequency and intensity of extreme weather events are expected to increase over the coming decades as a consequence of climate change, suggesting that the associated health impacts also could increase.

Indirectly, climate can affect health through alterations in the geographic range and intensity of transmission of vector-, tick-, and rodent-borne diseases, and food- and waterborne diseases, as well as through changes in the prevalence of diseases associated with air pollutants and aeroallergens. Climate change could alter or disrupt natural systems, making it possible for diseases to spread or emerge in areas where they had been limited or had not existed, or for diseases to disappear by making areas less hospitable to the vector or the pathogen (NRC 2001). Climate-induced economic dislocation and environmental decline also can affect population health.

The cause-and-effect chain from climate change to changing patterns of health determinants and outcomes is often complex and includes factors such as wealth, distribution of income, status of the public health infrastructure, provision of medical care, and access to adequate nutrition. Therefore, the severity of future impacts will be determined by changes in climate as well as by concurrent changes in non-climatic factors and by policies implemented to reduce negative impacts. It is important to note that even if total burdens of some climate-sensitive health outcomes decrease in the future, the attributable burden due to climate change is projected to increase.

The capacity of the U.S to develop and deploy effective and timely policies to address climate change is assumed to remain high throughout this century, thus reducing the likelihood of severe health impacts if appropriate programs and activities are implemented. However, the nature of the risks posed by climate change means that some adverse health outcomes may not be avoidable.

Extreme Weather Events

Heatwaves affect human health via heat stress, heatstroke, and death, as well as exacerbations of underlying conditions that can lead to an increase in mortality from all causes of death (not just heatstroke). Older adults, children, city-dwellers, the poor, and people taking certain medications are at the highest risk during a heatwave. The number of heat-related deaths are projected to increase with climate change (Confalonieri et al. 2007).

Recent projections of the impacts of climate change on heatwaves in the Midwest, using two definitions of a heatwave (the warmest average minimum temperatures over three consecutive nights in a given year, and exceedance of particular thresholds, suggested an increase in the average heatwave frequency of about 24% for Chicago (from 1.7 to 2.1 heatwaves per year); 50% for Cincinnati (from 1.4 to 2.1 heatwaves per year); and 36% for St. Louis (from 1.4 to 1.9 heatwaves per year) (Ebi and Meehl 2007). The average duration of heatwaves was projected to increase by 21% for Chicago (from 7.3 to 8.8 days); by 22% for Cincinnati (from 8.8 to 10.7 days); and by 38% for St. Louis (from 10.3 to 14.2 days). Combining changes in duration and intensity of heatwaves implies an overall increase of about 70% in the annual number of heatwave days for the Midwest by the late 21st century. Moreover, these extreme days will be hotter on average than at present. The projections also suggested that areas such as the Northwest, where heatwaves are not severe at present and where use of air conditioning is less common, future increases in heatwave intensity could result in more heat-related illnesses and deaths.

Hayhoe et al. (2004), the most recent study focused on the U.S., projected the impacts of extreme heat on heat-related mortality in California. Taking some acclimatization into account (but no change in the prevalence of air conditioning), assuming a linear increase in heat-related mortality with increasing temperature, and assuming no change in the population, expected heat-related deaths in Los Angles were projected to increase (from a baseline of about 165 excess deaths annually) two- to three-fold under a low emission scenario and five- to sevenfold under a high emission scenario by 2070–2099.

Applying the magnitude of the 2003 European heatwave to five major U.S. cities (Detroit; New York; Philadelphia; St. Louis; and Washington, D.C.), Kalkstein et al. (2008) concluded that a heatwave of the same magnitude would increase excess heat-related deaths by more than five times the average. New York City's total projected excess deaths exceeded the national summer average for heat-related mortality, with the death rate approaching annual mortality rates for common causes of death, such as accidents.

Climate change is projected to increase the intensity and frequency of floods, droughts, and windstorms in many regions (IPCC 2007). The impacts of an extreme event,

including loss of life and livelihood, are determined by the physical characteristics of the event, attributes of the location affected, and interactions of these with human actions and social, economic, institutional, and other systems. The adverse health consequences of flooding and windstorms often are complex and far-reaching, and include the physical health effects experienced during the event or clean-up process, or from effects brought about by damage to infrastructure, including population displacement. The physical effects largely manifest themselves within weeks or months following the event, and may be direct (such as injuries) and indirect (such as water and food shortages and increased rates of vectorborne and other diseases). Extreme weather events are also associated with mental health effects, such as post-traumatic stress disorder, resulting from the experience of the event or from the recovery process. These psychological effects tend to be much longer lasting and may be worse than the direct physical effects.

Air Pollutants

Climate change may increase concentrations of selected air pollutants, particularly ozone in some regions, and decrease concentration of other pollutants, such as particulate matter. Air pollution concentrations are the result of interactions among local weather patterns, atmospheric circulation features, wind, topography, and other factors. Climate change might affect local to regional air quality directly through changes in chemical reaction rates, boundary layer heights that affect vertical mixing of pollutants, and changes in synoptic airflow patterns that govern pollutant transport. Indirect effects may result from increasing or decreasing anthropogenic emissions via changes in human behavior, or from altering the levels of biogenic emissions because of higher temperatures and land cover change. Establishing the scale (local, regional, global) and direction of change (improvements or deterioration) of air quality is challenging.

There is extensive literature documenting the adverse health impacts of exposure to elevated concentrations of air pollution, especially particulates with aerodynamic diameters under 10 and 2.5 micrometers, ozone[1], sulphur dioxide, nitrogen dioxide, carbon monoxide, and lead. More is known about the potential impact of climate change on ground-level ozone than on other air pollutants.

Acute exposure to elevated concentrations of ozone is associated with increased hospital admissions for pneumonia, chronic obstructive pulmonary disease, asthma, allergic rhinitis and other respiratory diseases, and with premature mortality (e.g. NRC 2008). Outdoor ozone concentrations and activity patterns are the primary determinants of ozone exposure. The risk of mortality is not limited to those who are at very high risk of death within a few days of exposure (NRC 2008). A NRC committee concluded that "*the association between short-term changes in ozone concentrations and mortality is generally linear throughout most of the concentration range, … . If there is a threshold, it is probably at a concentration below the current ambient air standard*." (NRC 2008). In addition, there is limited evidence that chronic exposure to ozone increases mortality; if confirmed, then the total health burden of exposure to ozone would be much higher than current estimates (NRC 2008).

[1] The aerodynamic diameter of a particle determines the depth to which it will be inhaled into the lungs, and, therefore, the degree of damage that may be caused to various parts of the lung.

Changes in concentrations of ground-level ozone driven by scenarios of future emissions and /or weather patterns have been projected for Europe and North America (Confalonieri et al. 2007; Ebi and McGregor 2008). Increases in ozone concentrations will likely increase respiratory problems in susceptible individuals. Based on projections of county-level pollutant concentrations, summer ozone-related mortality was projected to increase by 4% in the New York area by the 2050s based on climatic changes alone (Knowlton et al. 2004).

Infectious Diseases

Climate change will likely have mixed effects on the health burdens of infectious diseases. Climate is a primary determinant of whether a particular location has environmental conditions suitable for the transmission of several vector-, rodent-, and tick-borne diseases, including West Nile virus, St. Louis encephalitis, Lyme disease, and dengue. A change in temperature may hinder or enhance vector and parasite development and survival, thus lengthening or shortening the season during which vectors and parasites survive. Small changes in temperature or precipitation may cause previously inhospitable altitudes or ecosystems to become conducive to disease transmission (or cause currently hospitable conditions to become inhospitable). The many determinants of infectious diseases often form an interconnected web with positive feedbacks between transmission dynamics and other factors, making modeling of the impacts of climate change challenging.

Several food- and waterborne diseases are climate sensitive, suggesting that climate change may affect their incidence and distribution. For example, studies report an approximately linear association between temperature and common forms of foodborne diseases such as salmonellosis (Confalonieri et al. 2007).

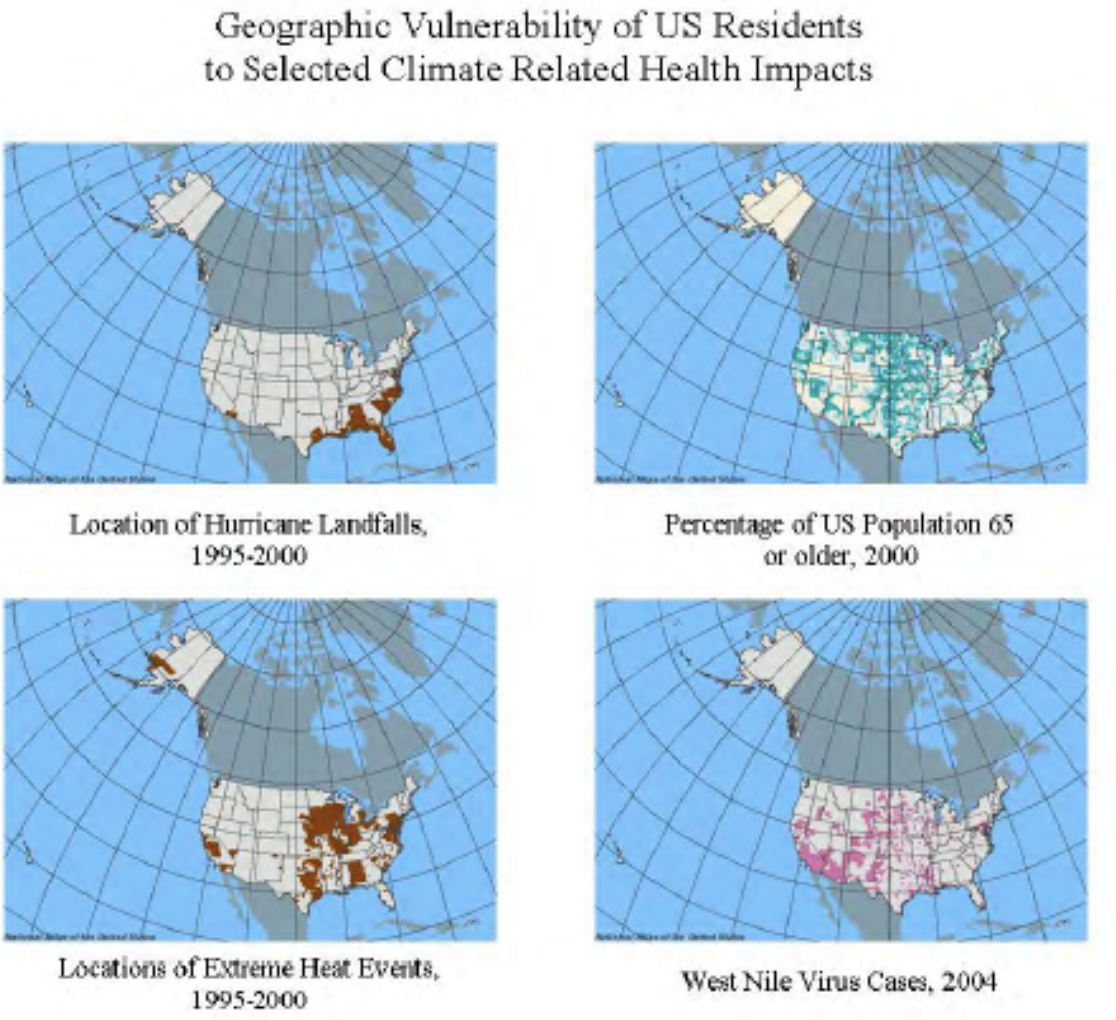
Recent studies report the occurrence of diseases in regions that have been considered too cold to support the pathogen (McLaughlin et al. 2005; Stephen et al. 2002). *Vibrio parahaemolyticus*, the leading cause of seafood-associated gastroenteritis in the U.S., is typically associated with the consumption of raw oysters gathered from warm-water estuaries (McLaughlin et al. 2005). One of the largest known outbreaks of *V. parahaemolyticus* in the U.S. occurred in Alaska, extending by 1000 km the northernmost documented source of oysters that cause this illness. Rising temperatures of ocean water seem to have contributed to the outbreak. An outbreak of *Cryptococcus gattii*, previously considered a tropical organism, occurred in southern Vancouver Island (Stephen et al. 2002). The incidence of medical visits for adverse reactions to insect stings and bites in three independent patient databases has increased during the past decade in Alaska, which has been associated with temperature changes in the same region (Demain et al in press).

Particularly Vulnerable Populations and Regions

Vulnerability to climate change will vary between and within populations. Sub-populations that are most vulnerable to the health impacts of climate change depend on the region of interest, the health outcome, and population characteristics, including human, institutional, social, and economic capacity, distribution of income, provision of medical care, and access to adequate nutrition. In general, children, older adults, those

with chronic disease, and the poor and disadvantaged are most at risk. Figure 1 shows counties with existing vulnerabilities to climate-sensitive health outcomes.

Figure 1: Counties with Existing Vulnerabilities to Climate-Sensitive Health Outcomes



2.0 Public Health Capacity to Address the Risks of Climate Change

Realistically assessing the potential health effects of climate change must include consideration of the capacity to manage the impacts of new and changing climatic conditions. Individuals, communities, governments, and other organizations currently engage in a wide range of actions to identify and prevent adverse health outcomes associated with weather and climate, such as heatwaves, wildfires, hurricanes, etc. Although these actions are generally viewed as having been largely successful historically, two recent surveys suggest that climate change will challenge the ability of current programs and activities to control climate-sensitive health determinants and outcomes (Balbus et al. 2008; Maibach et al. 2008; Wells Bedsworth 2008). Although some level of preparedness exists, there is a long way to go before the country's adaptive capacity is at a sufficient level. The preparedness gap includes not just infrastructure and

capacity, but also fundamental knowledge and the availability of reliable decision support tools. Preventing additional morbidity and mortality will require modification of current and implementation of new programs and activities to increase resilience to climate change, taking into consideration the local context, including socio-economic, geographic, and other factors. Research is needed to identify effective and efficient programs and activities, as well as how to successfully transfer lessons learned to other communities to assure protection of public health (Ebi et al. 2008).

The risks of climate change are likely to place extraordinary demands on public health programs and activities designed to protect the health and safety of U.S. residents and visitors. Increases in illnesses, injuries, and deaths would be expected unless policies and measures are developed to ensure effective functioning of these programs and activities. National, state, and local plans are needed to ensure sufficient public health capacity during and following extreme events such as flooding, storms and storm surges, and to address outbreaks of climate-related outbreaks of vector-, food-, and waterborne diseases. This capacity must be present, consistent, and effective in analyzing the safety of drinking water, monitoring for the appearance of vectorborne diseases, and providing acute and chronic care for persons suffering from the effects of climate-related events. Constraints include the financial, human, and institutional capacity at all levels of government and institutional service providers.

3.0 Managing the Projected Health Risks of Climate Change

Adaptation and mitigation are the primary approaches for addressing the risks of climate change; they are not mutually exclusive; co-benefits to human health can result concurrently with implementation of mitigation actions. Neither is sufficient in itself; focusing only on mitigation would leave communities ill-prepared for changes expected in the short term; and focusing only on adaptation would increase the amount of climate change to which future societies would need to cope.

Viewing adaptation within a risk management framework highlights some of the key differences between climate change and other environmental risk factors, including that the exposure cannot be prevented (i.e. increases in the frequency, intensity, and length of many extreme weather events); the rate of change is likely to increase over the next several decades; and the risks will vary over temporal and spatial scales, with the extent of impacts dependent on local and national factors. Therefore, adaptation will be a continual process of attempting to prevent adverse impacts from changing exposures and vulnerabilities.

Climate change will make it more difficult to control climate-sensitive health determinants and outcomes. Therefore, health policies need to explicitly incorporate climate-related risks in order to maintain current levels of control. In most cases, the primary response will be to enhance current health risk management activities. The health determinants and outcomes that are projected to increase with climate change are problems today. In some cases, programs will need to be implemented in new regions; in others, climate change may reduce current infectious disease burdens. The degree to which programs and measures will need to be augmented to address the additional pressures due to climate change will depend on factors such as the current burden of

climate-sensitive health outcomes, the effectiveness of current interventions, projections of where, when, and how the health burden may change with changes in climate and climate variability, the feasibility of implementing additional cost-effective interventions, other stressors that might increase or decrease resilience to impacts, and the social, economic, and political context within which interventions are implemented (Ebi et al. 2006). Examples of adaptation measures range from developing and deploying early warning systems and emergency response plans that specifically incorporate projections of climate change-related health risks to establishing surveillance programs in regions where projections suggest disease vectors may change their geographic range. Adaptation policies and measures need to consider how to effectively and efficiently reduce climate-related health risks in the context of sustainable development, considering projected demographic, economic, institutional, technologic, and other changes.

Because fossil fuel combustion is a source of urban air pollutants and greenhouse gases, policies to reduce greenhouse gas emissions may have health benefits in the near- and long-term. There are potential synergies in reducing greenhouse gas emissions and improving population health via sustainable transport systems that make more use of public transport, walking, and cycling.

4.0 The Human Impacts of Climate Change Outside the U.S. Can Affect the Population Health in the U.S.

Health security in the U.S. is influenced by risks outside her borders, as illustrated by the introduction and spread of West Nile virus and the concerns over the possible spread of SARS in the U.S. Globalization, increased travel and trade, immigration, and other factors can introduce new health risks, and disasters can increase the flow of refugees. *Plasmodium vivax* malaria, dengue fever, and other vectorborne diseases were once prevalent in the U.S., and the mosquitoes that can carry these diseases remain common in the U.S. Climate change is providing an opportunity for these mosquitoes to increase their geographic range; this could put more people at risk for introduced diseases if vector control programs are insufficient or not prepared. Better understanding of how climate change could alter the current distribution and incidence of climate-sensitive health outcomes throughout the world is needed to ensure U.S.-based programs and activities have adequate knowledge and resources to protect the health of our citizens.

5.0 Health Impact Assessments Are Needed of Policies and Technologies Being Developed to Reduce Climate Change Risks

The policies and technologies being developed to reduce the risks of climate change, from energy efficiency policies to carbon capture and storage, may have considerable health consequences. Therefore, a mechanism is required to assess the consequences of proposed mitigation and adaptation policies and measures prior to their adoption. Health Impact Assessments (HIAs) are a proven approach to ensuring that potential public health concerns are identified and addressed before they become a problem. According to the World Health Organization, “HIA provides decision makers with information about how any policy, programme or project may affect the health of people. HIA seeks to influence decision makers to improve the proposal.” (http://www.who.int/hia/en) HIAs

includes consideration of potential alternatives to reduce or mitigate potential health consequences of a proposed policy, as well as monitoring and evaluation of the adopted policy's implementation, to make corrections as needed to ensure the policy's effectiveness and its protection of human health. HIAs also can be used to identify the co-benefits of smart growth and development policies.

6.0 Federal Coordination is Needed of Research on the Health Impacts of Climate Change in the U.S.

Effectively addressing the health risks of climate variability and change will require wide-ranging responses from Federal and State agencies and departments. Because the health risks of and public health responses to climate change cover a broad range of issues, and because the risk and responses will change over temporal and spatial scales, there should be Federal coordination of programs and activities, within the CCSP or a similar organization, to ensure that funding focuses on critical research needs to address current gaps and those likely to arise within the next few decades. Programs and activities designed to address climate change and health issues should be established within all Federal agencies whose mandates include human health, including Departments of Commerce (specifically the National Oceanographic and Atmospheric Administration), Health and Human Services (particularly the Centers for Disease Control and Prevention), Homeland Security, Environmental Protection Agency, the National Institutes of Health, National Science Foundation, and the U.S. Geological Survey.

A robust research strategy to address the health risks of climate change, including the health aspects of climate mitigation and adaptation policies, should integrate four broad research activities: characterizing associations between weather/climate and health based on observed data; identifying observed effects of climate change on health; projecting health impacts using models; and identifying, prioritizing, evaluating, implementing, and monitoring effective and timely response options (including adaptation and mitigation). Key public health research categories that address these essential services include surveillance and monitoring; field, laboratory, and epidemiologic research; model development; development of decision support tools; and education and capacity building of the public and public health and health care professionals (Frumkin et al. 2008).

7.0 Research Funding to Understand the Health Impacts of Climate Change in the United States is Inadequate

Based on data available from agency websites, it appears that current Federal funding directed at understanding and addressing the health risks of climate change is approximately $3 million annually; this number would be approximately $1 million without new solicitations from U.S. EPA. These estimates are significantly less than funding figures provided to CCSP, and are inadequate to address the real risks that climate change poses for U.S. populations.

The inadequate level of U.S. funding appears to be due to the low priority placed on identifying and managing the health risks of climate change by Congress and the Federal

government. There are five over-arching goals for CCSP for fiscal year 2009 (U.S. CCSP 2008). Two are relevant to human health. Theme 4 is to understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes. However, the three identified focus areas do not explicitly mention human health as a priority (focus areas are to: improve knowledge of the sensitivity of ecosystems and economic sectors to global climate variability and change; identify and provide scientific inputs for evaluating adaptation options, in cooperation with mission-oriented agencies and other resource managers; and improve understanding of how changes in ecosystems (including managed ecosystems such as croplands) and human infrastructure interact over long time periods). Theme 5 is to explore the uses and identify the limits of evolving knowledge to manage the risks and opportunities related to climate variability and change; again, the three identified focus areas do not focus on human health (support informed public discussion of issues of particular importance to U.S. decisions by conducting research and providing scientific synthesis and assessment reports; support adaptive management and planning for resources and physical infrastructure sensitive to climate variability and change; build new partnerships with public and private sector entities that can benefit both research and decision-making; and support policymaking by conducting comparative analyses and evaluations of the socioeconomic and environmental consequences of response options). Understanding, avoiding, preparing for, and managing the health risks of climate change should be explicitly mentioned in CCSP goals.

More importantly, given the current and projected health risks of climate change in the U.S., Congress needs to allocate funds to Federal agencies whose mission mandates include human health; these agencies should maintain and enhance programs (and appropriate funding) to specifically address climate change risks in a timely and efficient manner. Based on the approach used for the Federal program in airborne particulate matter, and acknowledging the additional complexity of addressing the health risks of climate change, the level of Federal funding directed at climate change and health research should be more than $200 million annually (Ebi et al. submitted).

This suggested level of effort must rely on continued robust programs on research relevant to climate change and health. For example, U.S. EPA's Global Change Research Program recently completed a nine-year-long assessment of the implications of climate change for regional air quality that provides a basis for significant advances in understanding how projected changes in air quality could affect human health. NIEHS and CDC have conducted extensive research on asthma, vectorborne diseases, and other climate-sensitive health outcome that is required for understanding and predicting weather/climate exposure-response relationships, seeking evidence of whether climate change has affected human health, projecting the future geographic range and incidence of climate-sensitive health outcomes under a range of possible development pathways, and developing effective and timely adaptation and mitigation options.

Climate change is not a pollutant in the classical sense used in public health; it is a projected to fundamentally alter the systems on which our society relies, including air, water, agriculture, and ecosystems. Responses to climate change may alter energy, transportation, and other systems required for our societies to function. The health risks of climate change may arise from changes in any of these systems. Better understanding

is needed of these systems interactions with health, including risks and opportunities for interventions to improve population health. Ensuring that a Federal research program prepares the U.S. for the current and projected health impacts of climate change would be facilitated by establishing a standing committee within the National Academy of Sciences to advise on the size, priorities, and balance of such a program, through independent and regular evaluations of the state of knowledge and critical research gaps to address current and projected health risks.

Evidence is accumulating that climate change is adversely affecting human health in other parts of the world (i.e. Confalonieri et al. 2007). The lack of attention from the Federal government on the health risks of climate change to U.S. populations is needlessly putting people at risk.

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